Bio-optical Dynamics and the Forecasting of Bio-optical Variability in the Sea

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LONG-TERM GOAL

Research on oceanic bio-optical processes and the prediction of ocean bio-optical properties requires coupled physical-biological-chemical-optical models in three spatial dimensions and time with the capability of real data initialization and assimilation. The goal is to develop and prove such models, focusing specifically on the bio-optical component. Ultimately, this research is directed towards the understanding of optical and biological processes in the sea, their variability and their response and sensitivities to local and remote forcings.

OBJECTIVES

The scientific/technical objectives of this project are i) to develop the bio-optical model component of the Harvard Ocean Prediction System (HOPS); ii) to apply the bio-optical model to the study of real ocean dynamical processes which govern the variability of bio-optical properties and associated effects on biogeochemical and ecosystem dynamical processes in three dimensions; iii) to initiate the development of a predictive capability for nowcasting and forecasting bio-optical variability in the coastal ocean and the deep sea, and iv) to develop data assimilation capabilities for satellite ocean color and other bio-optical data.

APPROACH

The approach is to construct interdisciplinary models in order to study the physical, biological (ecosystem), chemical and optical dynamics, their interactions and dependencies. Ecological, bio-optical and biogeochemical processes are highly non-linear and span a wide range of interactive spatial and temporal scales.

Both historical and real-time data sets are being used to guide the construction of idealized examples and carry out dynamical studies with realistic fields. Dr. Jeff Dusenberry, the lead scientist on this project, has developed a protocol for calibrating the bio-optical component of a coupled physical-biological model. A simulated annealing based protocol was developed using available mooring time-series data. Sensitivity analyses are conducted to better understand sources of variability in biological and optical properties in the sea, and the responses of such properties to model parameter values and initial conditions. Data driven simulations in the New England Bight region and in the northeast Atlantic are used to further our understanding of physical-biological interactions and their effects on horizontal,

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vertical, and temporal variability in biological and optical properties. Predictive capabilities are developed and tested by carrying out simulation experiments in real-time.

WORK COMPLETED

A simulated annealing based calibration protocol which was developed and tested using data from the Biowatt mooring time-series, has been substantially improved over the past year, making the methodology more robust. We have initiated 1-D calibration exercises for the New England Bight region, using optical observations from the CMO mooring.

Data driven three-dimensional simulations in the New England Bight region and in the northeast Atlantic are underway. The New England Bight simulations are being used to explore relationships between physical and optical variability in the coastal region. The northeast Atlantic simulations are being used to quantify ecosystem model sensitivity to bio-optical parameterizations.

The biogeochemical/ecosystem model component, including the bio-optical model component which was developed under this project (Dusenberry et al., 2000), has also been successfully ported to several other ongoing studies, including studies in the Gulf of Cadiz, Massachusetts Bay, and the Gulf of Maine. Significant improvements have been made to the biogeochemical ecosystem model component, including the ability to model multiple classes of phytoplankton, each with its own bio-optical characteristics and the ability to model the effect of detritus on scalar irradiance independently from that of chlorophyll.

RESULTS

Calibration results from the Biowatt experiment suggest that open ocean productivity dynamics can be modelled equally well with a full spectral productivity model as with a computationally simpler scalar model. These calibration results and sensitivity analyses to parameter values, initial conditions, and bio-optical model formulation are currently being prepared for publication.

Simulations in the northeast Atlantic demonstrate that in the Spring the biological fields (e.g. chlorophyll) are predominately influenced by the meteorology in what is essentially a 1-D (vertical) framework, resulting in patterns which are then advected by the 3-D mesoscale circulation dynamics. Simulated biological fields develop patchiness on scales consistent with observations, and highly localized inverse relationships between zooplankton and chlorophyll occur, indicative of feeding events. These northeast Atlantic simulations form the basis of a publication which presents the bio-optical models developed under this project and explores the model sensitivities to bio-optical parameterizations (including scalar vs. spectral formulations), rate constants, and physical forcings.

Preliminary results from the New England Bight simulations demonstrate mesoscale advective events involving biological patchiness that result in what might appear to be local bloom events when observed from the perspective of a fixed mooring. Realistic fully-dimensioned simulations should thus aid in the interpretation of real ocean observations which are taken from fixed moorings.

IMPACT/APPLICATIONS

Coupled optical-biological-physical models comprise an important investigative tool for studying both biological and physical processes in the world’s oceans. From a management perspective, such models

are valuable not only as predictive tools, but as an aide for designing efficient sampling strategies.

TRANSITIONS

The bio-optical modules of HOPS are expected to make transitions with new releases of HOPS to the community. HOPS is currently being used at Naval Research Laboratories, the Naval Postgraduate School, the Jet Propulsion Laboratory (NASA), SACLANT Undersea Research Centre, Southampton Oceanography Centre (SOC), and universities in the United States, Japan, Greece, Italy, Turkey and Israel.

RELATED PROJECTS

We are collaborating with Prof. T. Dickey at UCSB to work with the Biowatt and Coastal Mixing and Optics (ONR) projects. These analyses will be used to develop predictive capabilities in both the open ocean and coastal regions.

The bio-optical models are being used in two other projects as well: the Littoral Ocean Observing and Predictive System (LOOPS) project (NOPP) and the Atlantic Fisheries Management and Information System (AFMIS) project (NASA). These simulations are being conducted in the Gulf of Maine and in Massachusetts Bay, and complement the New England Bight research quite well.

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